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Transverse Resistance Of Spikes and Nails

Architectural Engineering

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TRANSVERSE RESISTANCE OF SPIKES AND NAILS

BY

HOWARD FRASER ANDERSON

CARL BERNHARDT CARLSON

THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE

IN ARCHITECTURAL ENGINEERING

IN THE

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OF THE

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June 1, 1909

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

HOWARD FRASER ANDERSON and CARL BERNHARDT CARLSON

ENTITLED TRANSVERSE RESISTANCE OF SPIKES AND NAILS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Architectural Engineering

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TRANSVERSE RESISTANCE OF SPIKES AND NAILS

INTRODUCTION

The object of this investigation is to determine for practical purposes the safe resistance of connecting timbers made with spikes and nails. In order that this investigation should be of real value, ordinary materials available in this locality were used.

No data could be found relating to any tests of this nature previously made.

Knowledge of this subject is of much value to those engaged in building, since the transverse strength of nails in the construction of scaffolds is of considerable importance.

Wire nails ranging in size from eight penny to sixty penny were used. This range of sizes was chosen with the intention of testing only those generally used in structural work and subject to such loads. The timber used was short leaf yellow pine obtained from a local yard and of the quality used for ordinary buildings.

A factor of safety of unity was used because the test pieces were so made that the stress parallel to the fibres and the load causing a slip but one thirty-second (1/32) of an inch was assumed to be the

safe load. In practical building these connections would usually be made with at least one member of the connection taking stress across the fibres and hence this would resist a greater load and still remain safer than with all members under stress parallel to the fibres.

---METHODS---

The test pieces were made of 4" x 4" and 6" x 6" lumber cut in lengths of one and two feet. The fish pieces were made of 1" x 4" and 1" x 6" boards and were cut in the same lengths as the larger members. The fish pieces extended two inches above the ends of the main members and the joints were tested by compression endwise. Plate I will show the method used in construction.

A quincunx arrangement of the nails was used and they were arranged so that the same number of nails would be used on each side of the joint. The nails were spaced two inches on centers longitudinally; on the 4" x 4" pieces they were spaced one inch laterally and on the 6" x 6" pieces they were spaced one inch from each edge and the third row was placed in the middle.

The slip was measured by extensometers, reading to one-thousandth of an inch, and these were placed in the center of each side of the piece.

Load readings were taken at slips of 1/32" 1/16" 1/8" and every successive eighth inch up to 3/4". The extensometer recorded the slip as far as 1/4"; after this point the slip was measured with a steel scale.

The machine used was the three-screw Olsen Machine of a hundred thousand pound capacity.

A bearing, which should be exactly even, was difficult to arrange in making joints of the kind used and for uniform distribution of the load, ball and socket plates were used.

For the test pieces where nails of 40, 50, and 60 penny were used, the holes were drilled with bits about 1/32" smaller than the diameter of the nails. This was done to prevent cracking the lumber by driving the nails and thus reducing the shearing resistance of the test pieces.

The pieces were made in one and two foot lengths in order to determine whether the bearing power of the nails would vary directly with their number.

The condition of the wood was such that the results at failure varied considerably. Most of the test pieces failed by shearing along the nail lines, while practically all of the remainder failed by the pulling out of nails. In the case of failure by pulling out of the nails, these were bent. In some few instances, the wood failed by crushing along the top row of nails. There was no noticeable failure until

a slip of 3/8" was reached, that is, the condition of the wood and the nail heads showed no effect of load. After this point was reached the fish pieces could be seen to be forced a small amount from the main piece by the pressure. The ultimate load was reached at a slip of 3/4".

In considering the results gained from the investigation, several steps were taken. The first result is that shown on Sheet A. These curves show the relation between slips of 1/32" 1/16" 1/4" and 3/8" and the load per nail at each of these slips. A curve of this kind was plotted for each size of nail used. As shown here, the curves took the form of parabolas and increased rapidly after passing the thirty penny point.

Sheet B shows the relation between the length and name and the safe load in pounds. Safe load was taken as the load per nail at a slip of one thirty-second of an inch with a factor of safety of unity.

Sheet C shows the relation between the cross-section area of the nails used and the safe load in pounds. An average value of the points gives a straight line.

Sheet D shows the relation between the number of nails and the safe load in pounds for each size of nail. These curves are the final curves and are plotted from the data of the other sheets. From these curves, for a given load, the number of any

sized nails from eight to sixty penny required to safely resist this load, can be obtained. This sheet will prove useful in erecting scaffolding or other structural work where the amount of nails would be a notable item of expense. Also taking a certain load, say 400 pounds, eleven 60-penny nails would be needed to resist this load, while if 8-penny nails were to be used thirty would be required. In a pound of 60-penny nails there are just eleven, while there are one hundred and fifteen 8-penny nails in a pound. The ratio of the number of nails in a pound to the number required for any given load decreases with the size. This would show an economy in the use of a large number of small sized nails.

Sheet E shows the relation between the safe load in pounds and the diameter of the nails. An average value of the points gives a straight line.

Sheet F shows the relation between the diameter of the nails and the holding power for transverse and longitudinal stresses. For the longitudinal stress only two values, that for 10-penny and 20-penny nails, could be found and so a straight line was drawn.

Sheet G shows the relation between the name of the nails and the holding power for transverse and longitudinal stresses. These also vary in a straight line.

Sheet H shows the relation between the cross-

section area of the nails and the holding power for transverse and longitudinal stresses.

These last three sheets show that the holding power for longitudinal stresses increases rapidly with the size of the nails.

The tests in this investigation were in shear only. Comparison will now be made with some tests made in the resistance of nails to slipping under tension, with a view to obtaining some relation between the two kinds of tests.

The holding power of nails varies with so many conditions such as: length of time in wood, condition of wood, condition of surface of nail, etc., that no very conclusive comparisons can be deduced, but the conditions under which the results of this investigation and those made by the U. S. Government will be taken as the same.

The following table shows the holding power of nails in tension. The tension invariably reaches the maximum before the nail slipped.

---------*---------

Resistance to pulling out.

Nail	Size	Area	Stress
10 d	2.75 x .136	1.17	579
20 d	4.00 x .186	2.34	1220

Comparing these with the maximum transverse resistance.--

Nail	Size	Area	Stress
10 d	2.75 x .136	1.17	437
20 d	4.00 x .186	2.34	647

This shows that the adhesive power of the nail is considerably greater than its transverse resistance.

However, nails are more frequently subjected to transverse stress in construction as where two planks are nailed together to prevent sliding on one another.

Any projection or roughness left on the nail in manufacture will tear the fibres in driving it. This will decrease the pressure and elasticity of those fibres near the nail and prevent adjacent fibres from exerting their full pressure. However, if the surface is too smooth the fibre will not adhere strongly. If the projections are rounded, they act as a shelf and are advantageous. Experiments show that barbed nails have a greater holding power than plain nails, but from an economical standpoint alone they should not be used.

The holding power of a nail might be taken as directly proportional to the area of its surface in the wood, but this is not true. Bevons in experiments states that the resistance to drawing varies

as 3/2 d, where d is the depth driven in the wood. His results are tabulated as follows for a twenty-penny nail:

Depth	Stress in pounds
1	157
2	240
3	317

From experiments made by F. W. Clay on the bearing power of nails both in tension and transversely it was found that the tenacity lessens with the length of time that the nail stands when the wood is seasoned and that after weathering the general effect is the same, although shortly after being wet, the rusting of the nails causes them to adhere better. In these same experiments it was found that a nail driven perpendicular to the grain had a bearing power 50% greater than when driven parallel to the grain.

No very definite relation could be arrived at from the data available, between the bearing power of nails in tension and transversely. But this may be said, however, that the adhesive power of a nail is greater than the transverse resistance for a connection made with the same size nail.

No tests were made with cut nails. The manufacture and use of wire nails far exceeds that of cut nails as may be seen from the following statistics:

In 1903 there were manufactured--

	10,982,346	100-pound kegs of wire nails
and but	1,633,763	100-pound kegs of cut nails.

However, some data was found concerning cut nails in the investigation carried on by the U. S. Government at the Watertown Arsenal. The lumber used was Georgia pine and white pine. The following table will show some comparative values:

Nails in Shear.

Kind of wood	Size of nail	Stress per nail
Georgia Pine	12 d cut	950
"	20 d wire	745
White Pine	12 d cut	905
"	20 d wire	540

This shows that in hard wood the wire nail has a greater holding power per square inch by 6%, but that in soft wood the holding power is greater for the cut nail by 22%. The cut nail has the advantage of having a greater amount of surface and also of having a wedge shape.

CONCLUSIONS

Very little information could be found on the subject, but from available data and from the tests performed the following conclusions were deduced.

1. Cut nails are superior to wire nails in almost all cases, except in regard to ease.

2. If cut nails were pointed their efficiency would be increased against pulling by about 30%. This is due to the crushing of the fibres by the blunt end of the nail.

3. The tenacity of wire nails decreases in time.

4. The nail surface should be slightly rough, though not barbed as this decreases the efficiency about 32%.

5. Nails will give greater efficiency if wedge shaped, both sidewise and edgewise.

6. Nails used in tension should be about three times the thickness of the thinnest piece nailed in length and when used in shear about two times the same.

7. Nails driven perpendicular to the grain will hold about 50% more than when driven along the grain.

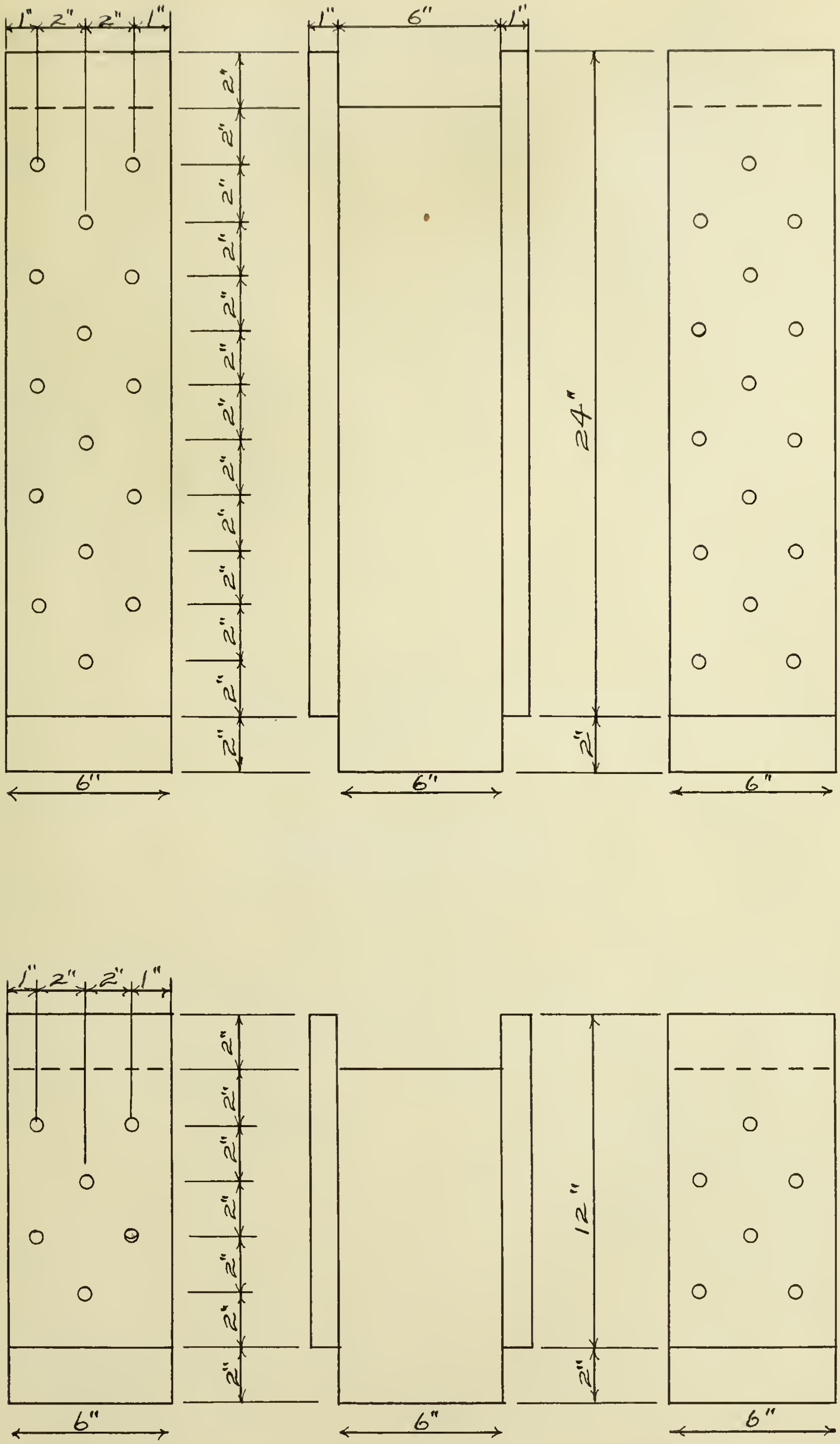
DATA OF TESTS

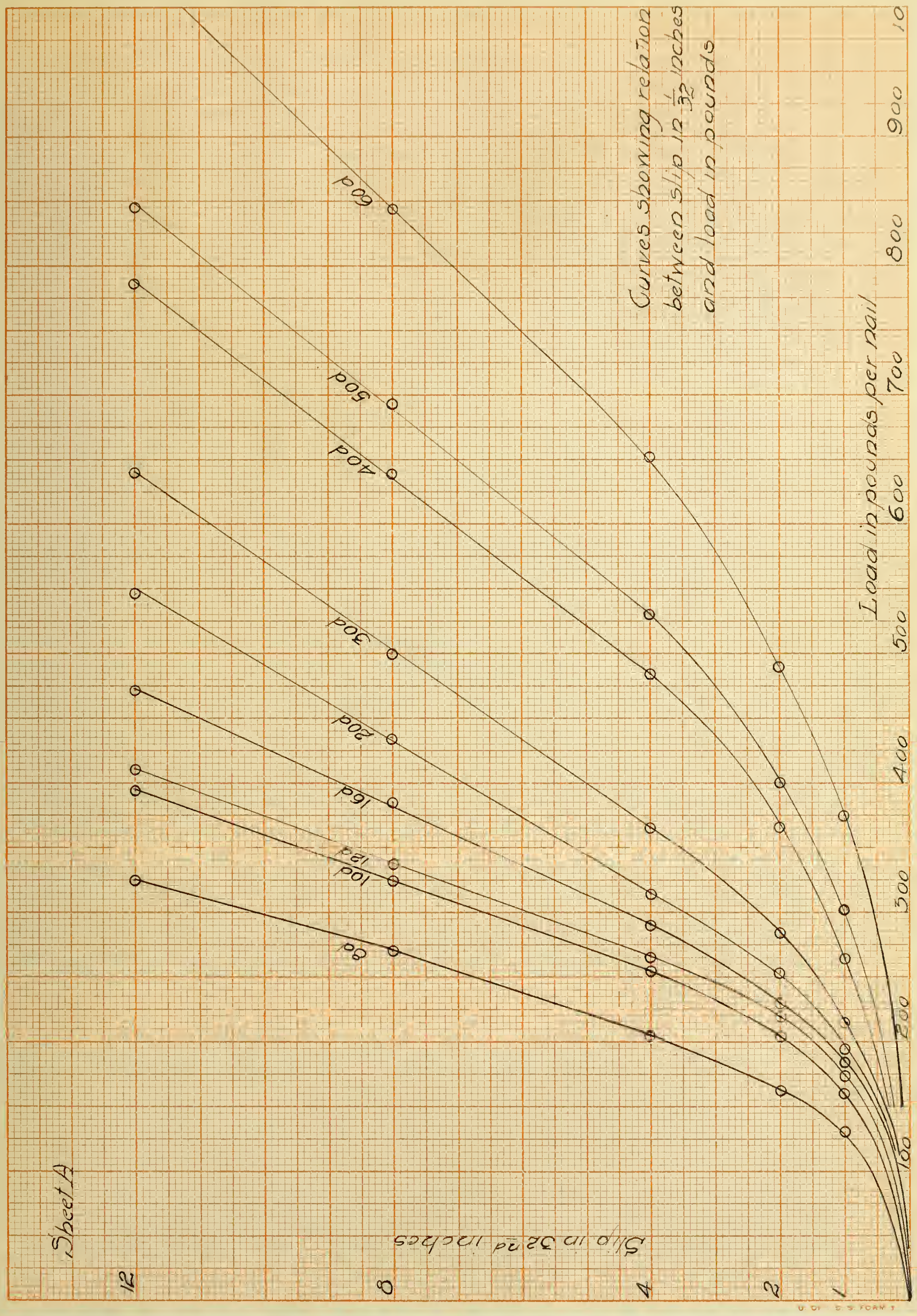
No. & Size		Slip of 1/32	Slip of 1/16	Slip of 1/8	Condition of failure
12	8 d	1500	1750	2100	Nails pulled through wood
12	8 d	1750	2000	2500	Nails pulled out
38	8 d	5450	6875	9100	Sheared along nail lines
38	8 d	5400	6500	8000	Crushed along top row
12	10 d	2000	2950	3850	Nails pulled out
36	10 d	5700	6800	8300	Bad knot on one side
36	10 d	5500	6500	7850	Crushed along top row
12	12 d	2000	2400	2900	Nails pulled through
12	12 d	2450	3200	3900	Nails pulled out
36	12 d	6100	7200	8650	Sheared along nail lines
36	12 d	6000	7600	8650	" " " "
12	16 d	2700	3650	4800	Nails pulled through
36	16 d	6200	7300	8900	Shearing and crushing
36	16 d	6300	7800	9400	Nails pulled through
54	20 d	8800	13800	19000	Crushed on top row
54	20 d	10250	13300	16400	" " " "
30	20 d	6200	7700	9800	Crushing on knot
12	30 d	3350	4900	6400	Nails pulled through
12	30 d	2700	3600	4700	" " "
30	30 d	5800	8600	11400	" " "
30	30 d	5850	8200	10500	" " "
12	40 d	3050	4400	6000	Nails pulled through wood
12	40 d	3200	4400	5650	" " " "
30	40 d	6700	9750	12100	Sheared along nail lines
30	40 d	8800	12500	16900	" " " "
30	50 d	7800	11100	15200	Poor lumber
30	50 d	7600	11850	16550	Sheared along nail lines
12	60 d	4400	6500	8800	Nails pulled through wood
12	60 d	4700	6500	8900	" " " "
30	60 d	6950	11050	17000	Sheared along nail lines
30	60 d	9100	12100	17350	Wood crushed at top

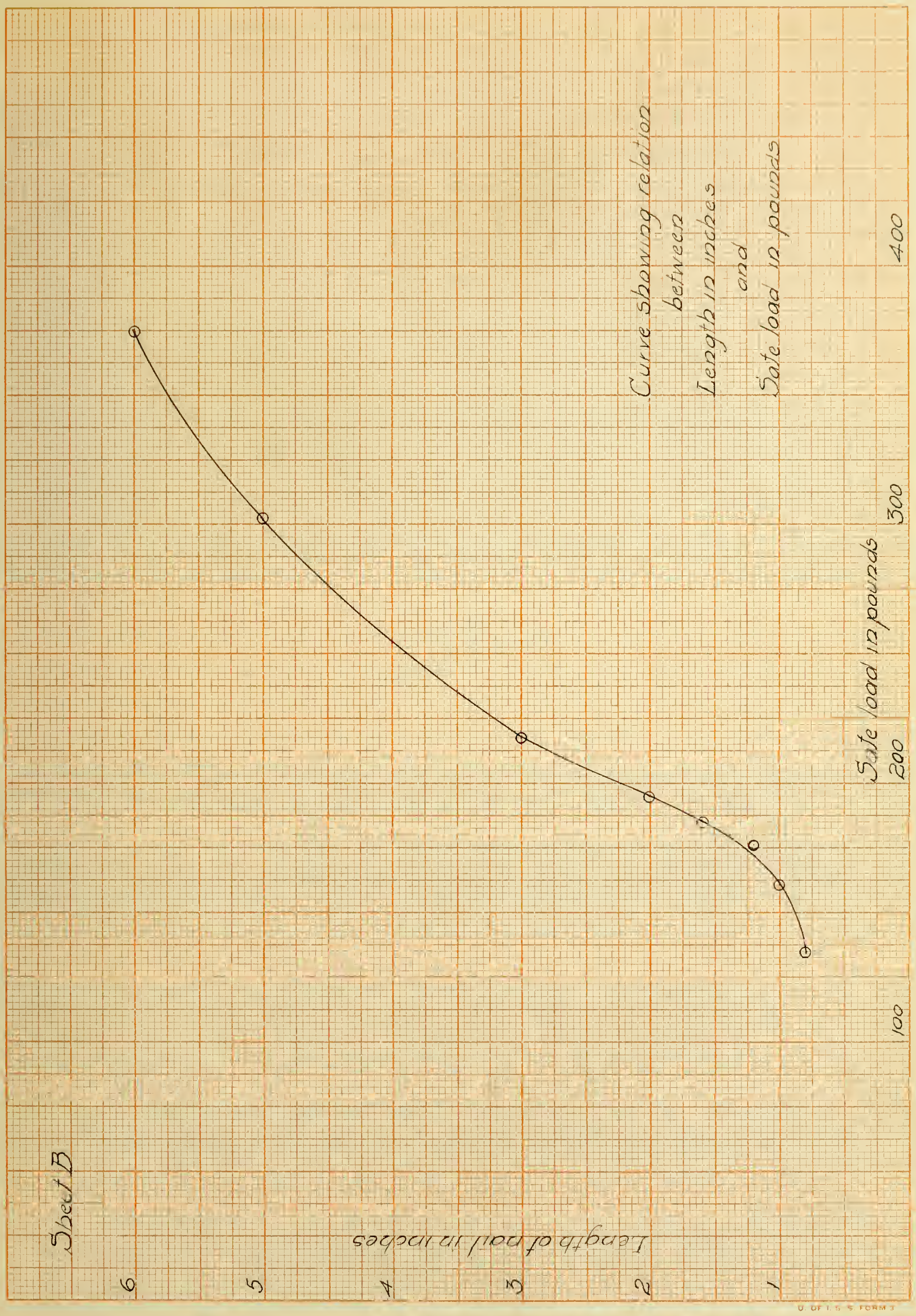
DATA OF TESTS (con)

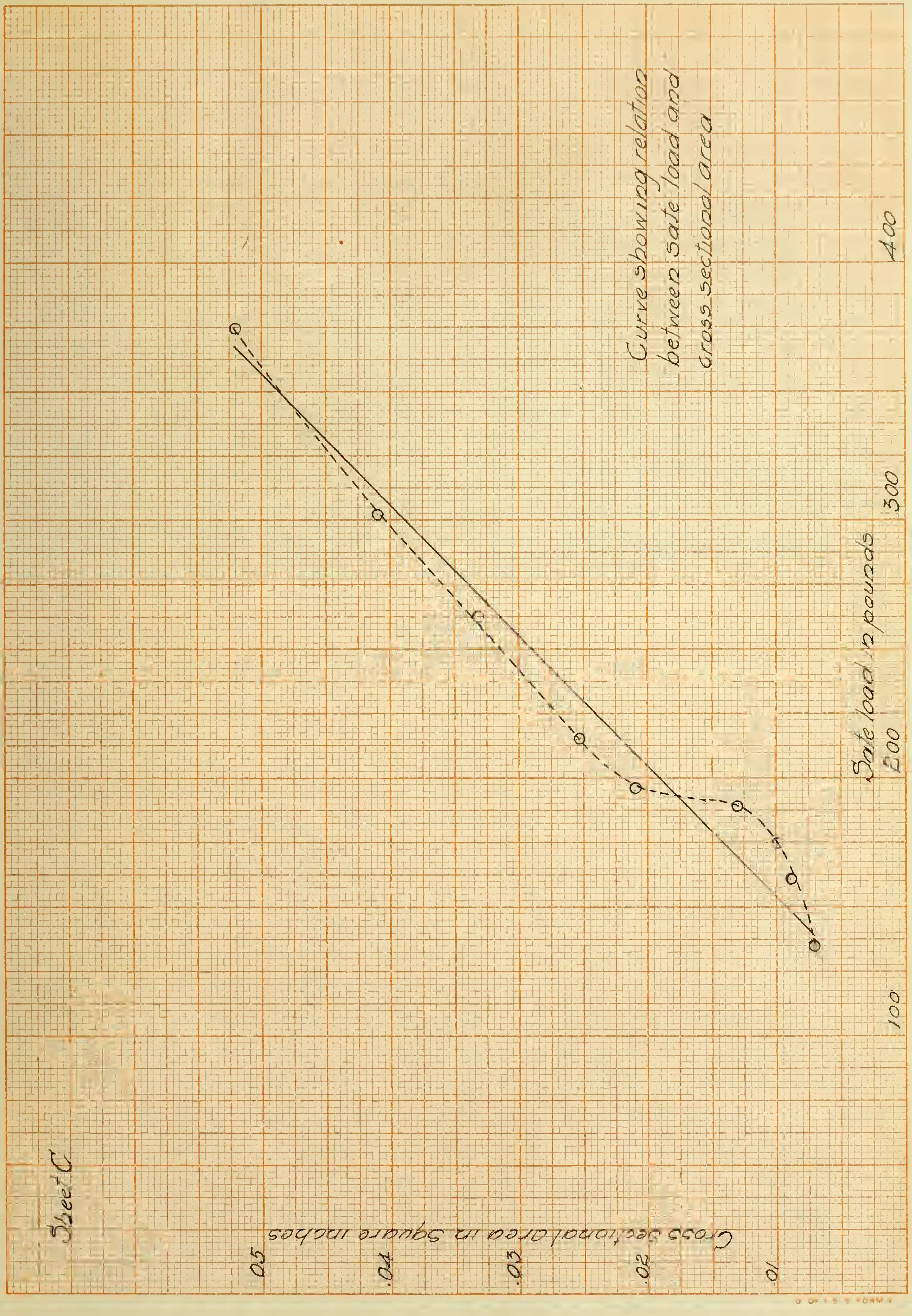
No. & Size		Slip of 1/4	3/8	1/2	Condition of failure
12	8 d	2850	3300	3800	Nails pulled through wood
12	8 d	3150	3850	4000	Nails pulled out
38	8 d	11800	12900	13400	Sheared along nail lines
38	8 d	11400	13200	15250	Crushed along top row
12	10 d	4525	5400	5450	Nails pulled out
36	10 d	11200	13300	13550	Bad knot on one side
36	10 d	10650	12700	13900	Crushed along top row
12	12 d	4100	5800	6900	Nails pulled through
12	12 d	4200	4850	4950	Nails pulled out
36	12 d	11350	13700	15750	Sheared along nail lines
36	12 d	11450	13800	15450	" " " "
12	16 d	5900	6600	6900	Nails pulled through
36	16 d	11050	12800	13700	Shearing and crushing
36	16 d	12700	15400	17600	Nails pulled through
54	20 d	23750			Crushed on top row
54	20 d				" " " "
30	20 d	13200	17400	19300	Crushing on knot
12	30 d	8100	9250	11100	Nails pulled through
12	30 d	6000	7100	8600	" " "
30	30 d	15200	17900	23300	" " "
30	30 d	13500	16250	20900	" " "
12	40 d	7700	10100	12000	Nails pulled through wood
12	40 d	7550	9000	11400	" " " "
30	40 d	16400	19800	26500	Sheared along nail lines
30	40 d	22750	26800	31300	" " " "
30	50 d	19500	23400	20500	Poor lumber
30	50 d	23400	26800	30600	Sheared along nail lines
12	60 d	12100	13800	16400	Nails pulled through wood
12	60 d	12200	13850	16500	" " " "
30	60 d	24100	28750	34700	Sheared along nail line
30	60 d	23400	31300	32000	Wood crushed at top

Plate 1

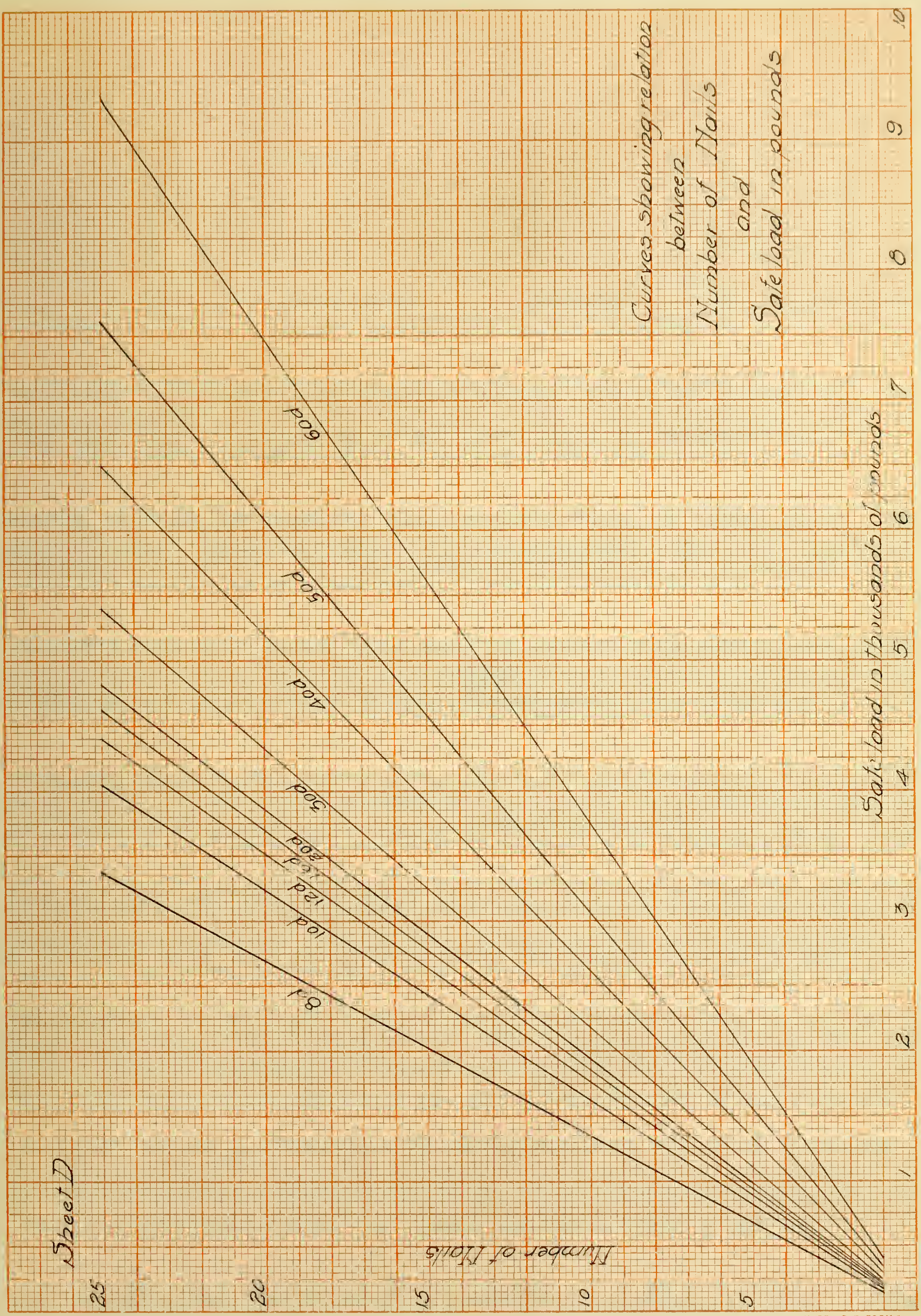



Curves showing relation between slip in $\frac{1}{32}$ inches and load in pounds
Load in pounds per nail
Slip in 32nd inches
Sheet A
60d
50d
40d
30d
20d
16d
12d
10d
8d
100
200
300
400
500
600
700
800
900
10
1
2
4
8
12


Sheet B
Curve showing relation
between
Length in inches
and
Safe load in pounds
Safe load in pounds
100
200
300
400
Length of nail in inches
1
2
3
4
5
6
U. OF I. S. S. FORM 3

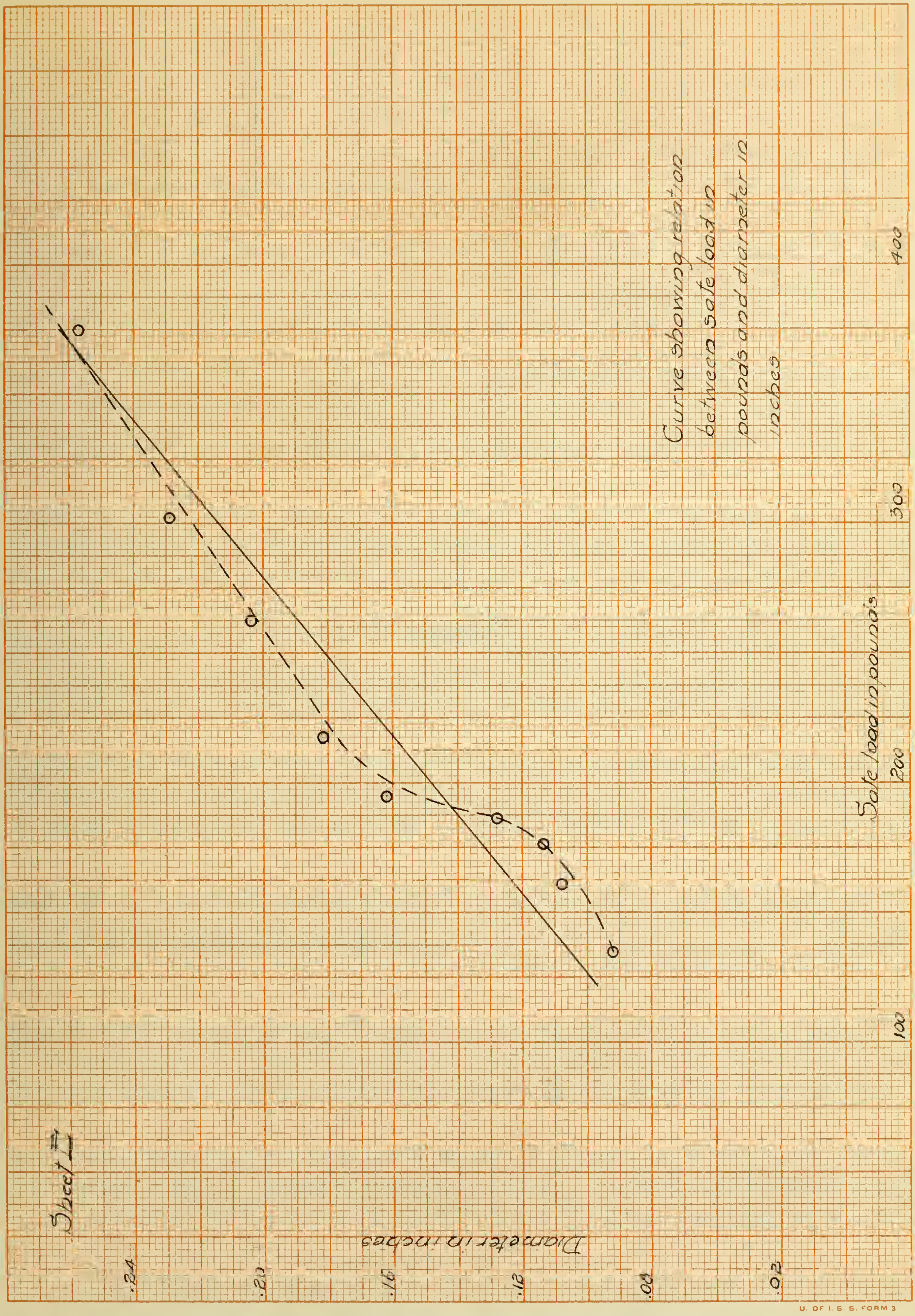


U OF I S S FORM 3

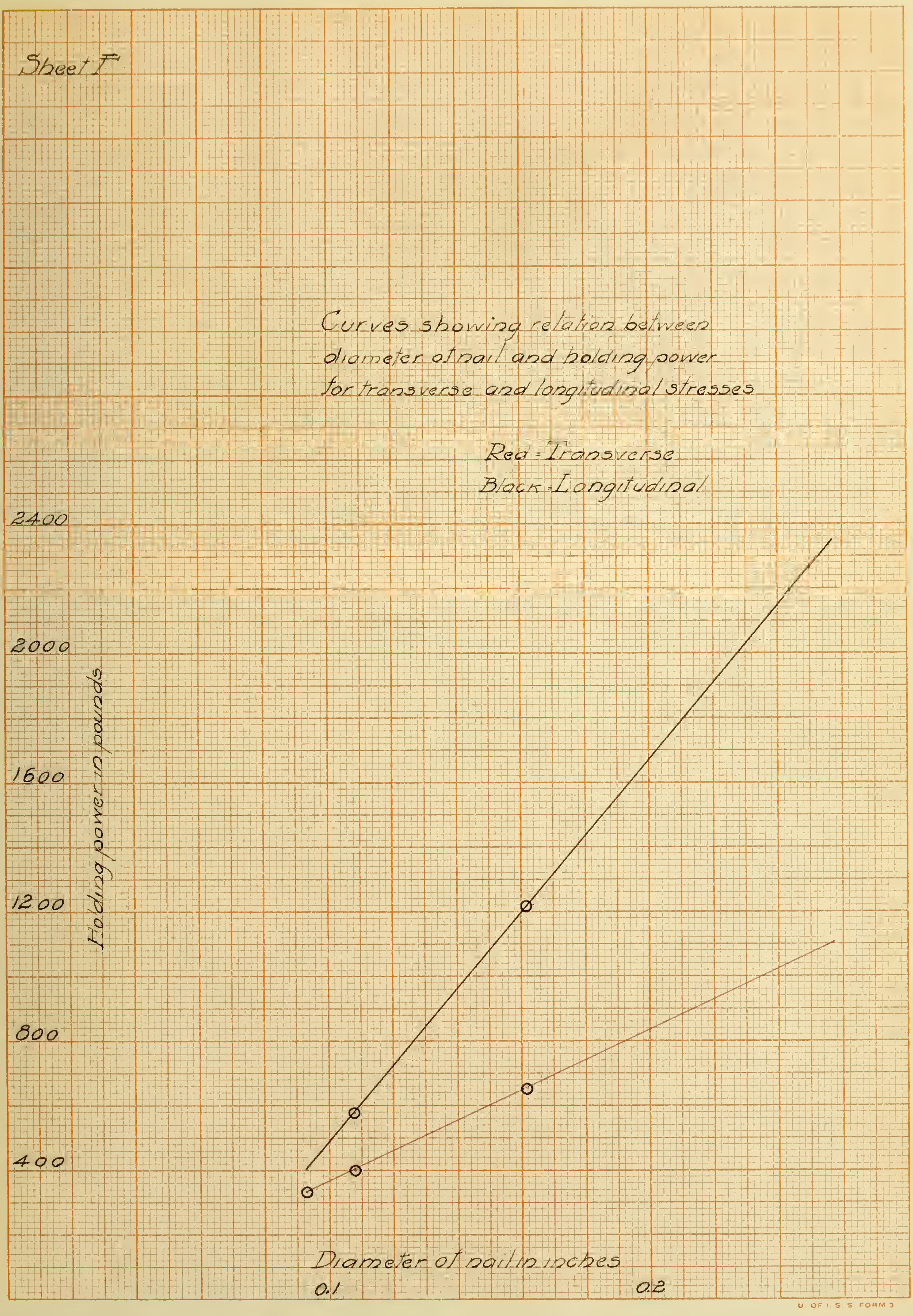


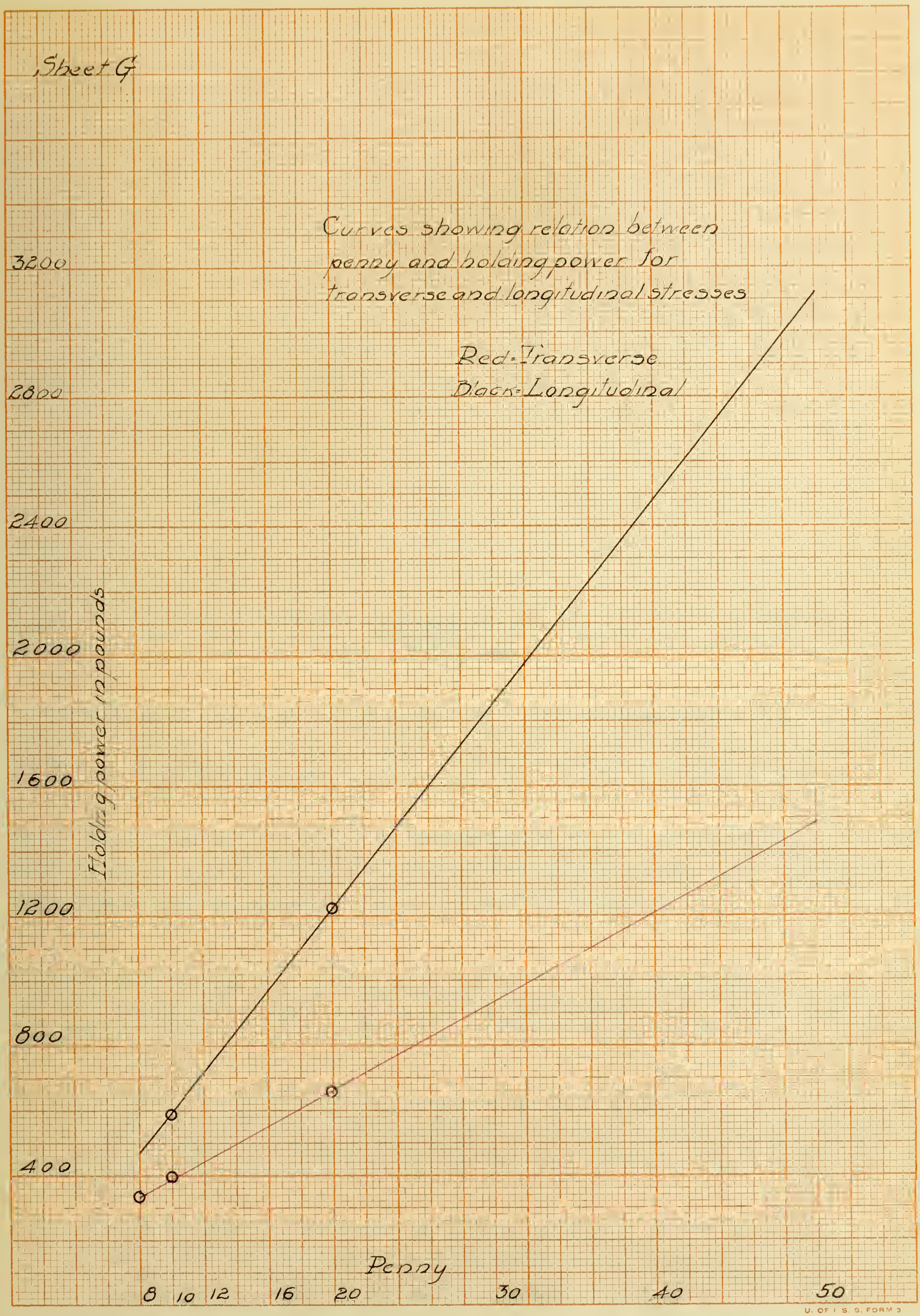
U. OF I. S. S. FORM 3

-17-


Curve showing relation between safe load in pounds and diameter in inches
Safe load in pounds
100
200
300
400
Diameter in inches
.24
.20
.16
.12
.08
0.2
Sheet
U. OF I. S. S. FORM 3

-18-


Sheet F
Curves showing relation between
diameter of nail and holding power
for transverse and longitudinal stresses
Red = Transverse
Black = Longitudinal
2400
2000
1600
1200
800
400
Holding power in pounds
Diameter of nail in inches
0.1
0.2
U. OF I. S. S. FORM 3


Sheet G
Curves showing relation between penny and holding power for transverse and longitudinal stresses
Red-Transverse
Black-Longitudinal
Holding power in pounds
3200
2800
2400
2000
1600
1200
800
400
Penny
8
10
12
16
20
30
40
50

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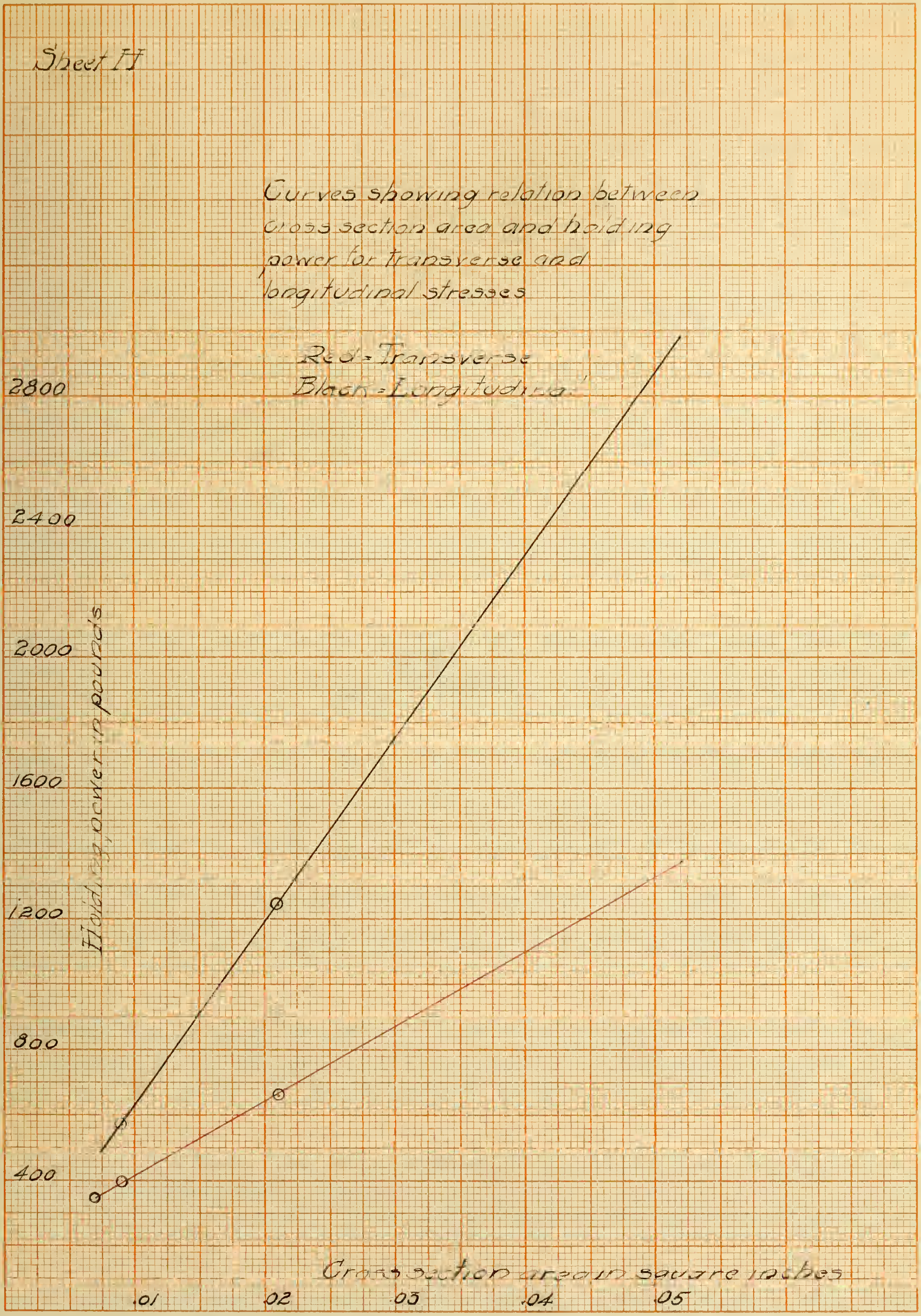
[illegible]


Sheet II
Curves showing relation between cross section area and holding power for transverse and longitudinal stresses
Red = Transverse
Black = Longitudinal
2800
2400
2000
1600
1200
800
400
Holding power in pounds
Cross section area in square inches
.01
.02
.03
.04
.05
U. OF I. S. S. FORM 3